Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

Canadian Science Advisory Secretariat (CSAS)

Research Document 2013/017

Central and Arctic Region

Results of Foxe Basin walrus (*Odobenus rosmarus rosmarus*) surveys: 2010-2011

R.E.A. Stewart, J.W. Hamilton and J.B. Dunn

Fisheries and Oceans Canada
Freshwater Institute
501 University Crescent
Winnipeg, MB R3T 2N6
Canada

May 2013

Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

© Her Majesty the Queen in Right of Canada, 2013
ISSN 1919-5044

Correct citation for this publication:

Stewart, R.E.A., Hamilton, J.W., and Dunn, J.B. 2013. Results of Foxe Basin walrus (*Odobenus rosmarus rosmarus*) surveys: 2010-2011. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/017. iv + 12 p.

ABSTRACT

Through periods of August and September of 2010 and 2011 a project was undertaken to enumerate walrus in Foxe Basin, a portion of the Central Arctic walrus population. Satellite-linked radio transmitters were deployed in 2010 (11) and 2011 (23) prior to concurrent boat and aerial surveys. Based on previous observation and close consultation with the Hall Beach Hunters and Trappers Association and the Igloolik Hunters and Trappers Organization, surveys were designed to capture the maximum number of walrus on land. The surveys attempted to include all known and suspected walrus haulout sites in Foxe Basin, along with most of the coastline and islands. Survey crews captured digital imagery of walrus on land and in the water. These were used for counting and generation of a Minimum Counted Population (MCP). Weather and logistics caused the surveys to span several days, during which walrus could move from one haulout to another. To reduce the probability of consequent double-counting, a time-distance criterion was applied, which resulted in final counts being based on fewer haulout sites than were examined. The MCP of haulout counts only (MCP_{HO}) was adjusted to account for walrus not hauled out at the time of the surveys using an estimate of the maximum proportion hauled out concurrently (0.74) derived from other studies ($MCP_{HO}/0.74$). We also used data from satellite tags in operation in Foxe Basin at the time of the surveys to adjust the MCP_{HO} for walrus not hauled out during the surveys (MCP_{HO}/% tags dry). In 2010, the MCP was 3,861; $MCP_{HO}/0.74$ was 5,200 (Coefficient of Variation (CV) = 0.022); and MCP_{HO}/% tags dry was 6,480 (CV = 0.383). In 2011, MCP was 6,043; $MCP_{HO}/0.74$ was 8,153 (CV = 0.021); and MCP_{HO}/% tags dry was 10,379 (CV = 0.42). In both years, coverage was incomplete and the number of haulouts included in the final estimates was further reduced to avoid double counting. In 2011, there may have been 13,452 (CV = 0.43) walrus present if it is assumed that the tagging data from a single haulout were representative of other haulouts. However, it is not possible to test this assumption with current information.

Résultats des relevés sur le morse du bassin Foxe (*Odobenus rosmarus rosmarus*) : 2010-2011

RÉSUMÉ

Pendant certaines périodes des mois d'août et septembre 2010 et 2011, un projet a été mis en place pour dénombrer les morses du bassin Foxe, qui forment une partie de la population de morses du centre de l'Arctique. Des émetteurs radio en liaison avec un satellite ont été déployés en 2010 (11) et 2011 (23) avant des relevés aériens et maritimes simultanés. À partir d'observations précédentes et de consultations étroites avec les membres de l'Association des chasseurs et des trappeurs de Hall Beach et celle d'Igloolik, des relevés ont été conçus pour dénombrer le plus grand nombre de morses qui se trouvaient sur les terres. Les relevés cherchaient à comprendre toutes les échoueries connues et présumées du bassin Foxe, avec la plupart des côtes et des îles. Les équipes chargées des relevés ont capturé des images numériques de morses à terre et en mer. Elles ont servi à les dénombrer et à définir la valeur de la « population minimale comptée » (PMC). En raison du climat et de questions de logistique, les relevés se déroulaient sur plusieurs jours, pendant lesquels les morses pouvaient aller d'une échouerie à l'autre. Pour réduire la probabilité de comptage double qui pouvait en résulter, un critère temps-distance a été appliqué et le dénombrement final se fonde donc sur un nombre d'échoueries inférieur au nombre examiné. La PMC obtenue seulement sur les échoueries dénombrées (PMC_{HO}) a été ajustée pour prendre en compte les morses qui n'étaient pas sur des échoueries au moment des relevés, au moyen d'une estimation de la proportion maximale de morses se trouvant simultanément sur des échoueries (0,74) tirée d'autres études (PMC_{HO}/0,74). Nous avons aussi employé des données d'étiquettes émettrices en activité dans le bassin Foxe au moment des relevés pour préciser la PMC_{HO} des morses qui n'étaient pas sur les échoueries pendant les relevés (PMC_{HO}/% d'étiquettes sèches). En 2010, la PMC, PMC_{HO}/0,74 et PMC_{HO}/% d'étiquettes sèches étaient respectivement de 3 861, 5 200 (coefficient de variation (CV) = 0,022) et 6 480 (CV = 0,383). En 2011, ils étaient respectivement de 6 043, 8 153 (CV = 0,021) et 10 379 (CV = 0,42). Les deux années, la couverture était incomplète et le nombre d'échoueries comprises dans les estimations finales ont été réduites pour éviter les doubles comptages. En 2011, le nombre de morses présents aurait pu s'élever à 13 452 (CV = 0,43) si l'on suppose que les données des étiquettes d'une seule échouerie sont représentatives des autres échoueries. Il est toutefois impossible de mettre à l'épreuve cette hypothèse avec les renseignements dont nous disposons.

INTRODUCTON

In 2007, Ecosystems and Fisheries Management (EFM) within Fisheries and Oceans Canada (DFO) requested Science advice on total allowable harvest for each of the walrus stocks found within the Nunavut Settlement Area, including Foxe Basin, as requested by the Nunavut Wildlife Management Board (NWMB). In 2008, Science produced a Research Document evaluating the existing information (Stewart 2008a), but concluded that due to lack of information on stock estimates, it was not possible to provide the advice as requested. This information is needed to finalize draft Integrated Fisheries Management Plans for these stocks and for NWMB consideration in establishing harvest limits. Sustainability can be assessed by examining population trends or by estimating allowable removals and comparing them to current removals. Both need current estimates of population size (absolute or relative) and here we report on efforts to obtain an estimate of absolute population size of walrus in Foxe Basin.

DFO and the North Atlantic Marine Mammal Commission (NAMMCO) recognized seven extant stocks in Canada (Figure 1): Baffin Bay (BB), West Jones Sound (WJS), Penny Strait-Lancaster Sound (PS-LS), Northern Foxe Basin (N-FB), Central Foxe Basin (C-FB), Hudson Bay Davis Strait (HB-DS), and South & East Hudson Bay (S&E-HB) (Stewart 2008b). Recent mtDNA data grouped walrus samples from the first six stocks into two clusters, identified as the high Arctic (BB, WJS, PS-LS) and central Arctic (N-FB, C-FB, HB-DS) populations (Shafer *et al.* 2013). The two stocks in Foxe Basin were distinguished from each and from HB-DS on the basis of lead isotope and trace element profiles (Outridge and Stewart 1999, Outridge *et al.* 2003). Walrus in Foxe Basin also appear to be larger than those from Hudson Bay (Garlich-Miller and Stewart 1998). Isotope analysis of Growth Layer Groups (GLGs) suggested some exchange with HB-DS (Stewart *et al.* 2003) at a rate which is sufficient to eliminate genetic differences (Shafer *et al.* 2013). Tagging studies (Dietz *et al.* 2013) demonstrated a link between southeast Baffin Island and West Greenland. Andersen *et al.* (2013) found no significant genetic differences found between these two areas and significant differences between these two areas and Hudson Strait. However there was also evidence of significant numbers of migrants (non-breeding) from Hudson Strait to both southeast Baffin and West Greenland areas.

The walrus in Foxe Basin therefore represent a group of walrus which live their lives differently than those in HB-DS, to whom they are related. Isotopic differences, and morphological differences used by Inuit to identify two groups in Foxe Basin (DFO 2002), are not detectable from the air so we grouped N-FB and C-FB in our surveys.

METHODS

Methods used to survey walrus in Foxe Basin were similar to those reported by Stewart *et al.* (2013a). Using similar methods, estimates have been calculated for BB (Stewart *et al.* 2013b) and a small portion of the HB-DS stock (Stewart *et al.* 2013c). In brief, the scientific literature, *Inuit qaujimaningit*, or IQ, and other traditional knowledge were used to identify former, current, and potential haulout sites in northern Foxe Basin (Figure 2). Government of Nunavut (GN) researchers added another two haulout sites in 2010. Sites were examined repeatedly each year, as weather and logistics permitted, in the season when maximum numbers were expected to occur based on IQ.

In 2010 and 2011, aerial surveys were conducted using a de Havilland Canada DHC- Twin Otter. Target altitude was 300 m ASL, at about 210 kph; the aircraft flew approximately one km off of the coastline. There were at least two observers, one on each side, on all flights, but

Figure 1. Schematic illustration of the distribution of walrus stocks in Canada. BB = Baffin Bay; WJS = West Jones Sound; PS-LS = Penny Strait-Lancaster Sound; N-FB = northern Foxe Basin; C-FB = central Foxe Basin; HB-DS = Hudson Bay-Davis Strait; S&E-HB = south and east Hudson Bay.

Figure 2. Survey area and haulout sites in Foxe Basin.

usually also a third observer. The flight crew also contributed observations. When walrus were seen, the numbers were estimated independently by each observer and oblique aerial photographs were taken when possible using digital cameras (Canon EOS 30D or 40D and EFS17-85 mm or 70-300 mm zoom lens with image stabilizer). Cameras were synchronized with a GPS used to record tracks and sightings. The survey tracks were mapped using GPS software (Garmin, Olathe, Kansas, USA) and photos were geocoded, using this information.

Boats and survey crews (two from each community) were hired and trained in walrus survey methods. They were supplied with binoculars, digital cameras, GPS, and other necessary gear to conduct an effective survey. Boat surveys were conducted on or around the same dates as the aerial surveys, depending on weather and water conditions. GPS tracks and photos are being assessed and analyzed to determine the utility of boat surveys for the future. The boat crews collected ground- and water-level photos, as did the DFO crew while conducting satellite tagging and biopsy exercises. It is understood the boat-based photographs underestimate walrus at haulout sites since the images are captured from the same plane as the walrus; animals behind the first row have a high probability of being unavailable for counting.

Photographs from each walrus encounter were examined in Adobe PhotoShop® CS2 and modified in size, contrast, and brightness to produce the clearest image for counting. Coloured dots were super-imposed on each enumerated walrus and the image re-examined for missed animals. Previous studies that compared independent counts from the same images conducted by two counters indicated their individual counts were nearly identical (R^2=0.97; Counter A = 0.01 + 0.97 × Counter REAS) (Stewart *et al.* 2013a). In the present study new counters were calibrated against Counter REAS using 41 images and congruence was deemed satisfactory (Counter B = 0.90 + 1.01 × Counter REAS, R^2 = 0.991; Counter C = -0.07 + 1.04 × Counter REAS, R^2 = 0.997).

Surveys of adjoining areas were often separated by a few days, with potential for walrus to move among sites. Until area-specific movement rates can be examined, we used 45 km/24 h as the criterion by which to reject counts that were not sufficiently separated in time and space to preclude double-counting (Stewart *et al.* 2013c). Distances were estimated using MapSource® (version 6.16.3), rounded to the nearest five km.

The survey is designed to directly enumerate walrus at haulouts sites (colony counts) (Buckland and York 2009). While akin to determination of the minimum number alive (MNA, Krebs 1966) we applied the phrase 'Minimum Counted Population' (MCP) to avoid any inference that we had tagged and recaptured walrus (Krebs 1966). The largest counts of walrus that satisfied the distance-time criterion were added to produce the MCP. Walrus counted opportunistically in the water between haulouts were included in the MCP.

To obtain information on movement among haulouts and an adjustment factor for counts (and possibly locate new haulouts), a DFO field crew was flown to walrus haulout sites using a Bell 206L helicopter. A total of 34 (11 in 2010; 23 in 2011) SPOT-5 satellite-linked radio tags (Wildlife Computers, Redmond, Washington, USA), attached to custom made deployment tips, were successfully deployed onto walrus using an Excalibur crossbow, without the need to sedate the walrus.

To convert MCP of walrus hauled out (MCP_{HO}) into an estimate of total stock size, two factors were considered: (1) not all animals hauled out are available or detectable for counting, and (2) the proportion of the population at haulout at the time of the survey is unknown. To address the first, we attempted to apply the Bounded Count Method (Olesiuk *et al.* 1990, Thompson *et al.* 1997, Walker *et al.* 2008, Stewart *et al.* 2013a) which relies on replicate counts at several haulouts. In both years, only Manning Island and South Ooglit Island provided replicates and

produced bounded count estimates lower than MCP in both years. These estimates were not carried forward.

It is unlikely that all walrus in an area are hauled out at the same time. Previous studies (Stewart *et al.* 2013a-c) used pooled data from Alaska, Greenland and Norway (Table 1) to suggest the maximum proportion of a population hauled out concurrently is 0.7429, rounded to 0.74, with binomial variance (Zar 1999, Standard Deviation (SD) = 0.015). We applied this adjustment to MCP_{HO} values. We also used data from our tags which were known to be functional at the time of the survey. We used the proportion of transmitting tags registering 'dry', regardless of location, in the clock-hour of the photo-captures. To be scored as 'dry' the tag had to report 'dry' for at least 45 min in the hour. Again the variance was the binomial variance.

Variances of the MCP and estimated HO_{max} were combined following Thompson and Seber (1994) for an estimated constant detectability:

$$\mathrm{var}(\tilde{N}) = \frac{\mathrm{var}(MCP_{HO})}{P^2} + MCP_{HO}\frac{1-P}{P} + \frac{\tilde{N}^2}{P^2}\mathrm{var}(P)$$

where $\tilde{N}$ is the estimated total population with variance var($\tilde{N}$); MCP_{HO} is the count with variance var(MPC) = 0; and P is the proportion of the total population hauled out (either 0.74, var(P) = 0.0002 (Table 1) or calculated from concurrent tags and their binomial variances.

Table 1. Maximum proportions of tagged walrus dry (i.e., hauled out) concurrently. Variance for each proportion (p) is the binomial variance (p(1-p)/(n-1) for small samples (Zar 1999). Weighted average and associated variance (Standard Deviation) is after Dixon and Massey (1969).

Location/ season	Year	Number of tags (dry/total)	Maximum proportion hauled out (SD)	Source
Alaska/ summer	1990	5/6	0.833 (0.142)	Hills 1992
Svalbard/ August	2003 2004	6/9 9/11	0.667 (0.095) 0.818 (0.167)	Lydersen *et al.* 2008, C. Lydersen pers. comm. 2011
Alaska/ April	2004 2006	8/12 17/24	0.667 (0.122) 0.708 (0.167)	Udevitz *et al.* 2009, M. Udevitz pers. comm. 2011
NE Greenland/ August	2009	7/8	0.875 (0.125)	Born, unpubl. data
Average		0.743 (52/70)		
Weighted Average			0.7429 (0.015)	

RESULTS

We examined haulouts in 2010 and 2011 (Figure 2). In 2010, the MCP was 3,861, including 13 at sea, observed on 29 and 31 August and 1 September at six haulouts that satisfied the distance criterion. Assuming the MCP_{HO} was obtained when the maximum proportion (0.74) hauled out produced an estimate of 5,200 (CV = 0.022) walrus (Table 2). There were no tags active at the time, as the tags were deployed on those days. However, on 12 and 13 September 2,409 walrus were counted at two haulouts (plus 25 at sea) when eight tags were transmitting. Another haulout was empty and a fourth had many walrus but was disturbed by boats so no count was obtained. Using just those two haulouts and the proportion of the eight tags which were 'dry' in the hour of the counts (2/8, SD = 0.16, on 12 September and 4/8, SD = 0.19, on 13 September) to adjust each count, produced an adjusted sum of 6,480 (Table 2). The summed variance produced a CV of 0.383 (95% Confidence Limits (CL) = 1,615-11,346).

In 2011, six of six haulouts examined yielded an MCP_{HO} of 6,033 plus 10 at sea, on 12 and 13 September. Adjusting the MCP_{HO} by the maximum proportion hauled out produced an estimate of 8,153 (CV = 0.021) (Table 2). Eighteen tags were functioning at the time of these counts however all but one were near a single haulout that was disturbed by boats on 12 September, before the counts were made. We therefore used the second highest count (4,484), made at five haulouts on 19 September when 12 tags remained functional. All but one of the tags were still in a small area around South Ooglit Island so we eliminated the distant tag and applied the South Ooglit tag data only to the count at South Ooglit Island. We counted 3,368 walrus at South Ooglit Island when 4/11 (0.36, SD = 0.15) tags reported dry, producing an estimate of 9,262 (CV = 0.42, 95% CL = 1,666-16,858) to which 1,117 walrus at three other haulout sites (counts of 8; 1,108; and 0) were added to equal 10,379 (CV = 0.42) (Table 2).

DISCUSSION

Numbers of walrus present in photos are difficult to count primarily due to the oblique angle which allows animals in the foreground to obscure those behind (Figure 3). Even more walrus are obscured in photos from ground/sea level. To some extent, all our counts of large groups under-represent the number present by some unknown factor. The tag-adjusted estimate in 2010 relies on a sea level photo of Manning Island on 13 September in which 831 of the total 2,409 (approximately 35%) were tallied. This resulting estimate of 6,480 is probably an underestimate. Similarly, the MCP in 2011 on 12-13 September used a sea level image of 995 enumerated walrus (out of 6,033 counted on land, approximately16%) which produced an estimate (MCP_{HO}/0.74) of 8,153. Both estimates are probably under estimates. We propose to address this bias in the future with vertical photography of higher resolution (Figure 4).

To date, we have been unable to examine every known haulout in a short enough time to combine all the counts. Six of 10 possible sites (Figure 2) were used in the MCP in 2010 but only 2/10 in the estimate using proportion of tags 'dry'. In 2011, the numbers were six and five respectively, although only the count at South Ooglit could be adjusted. Of those 10, we have not confirmed that walrus still haul out on Tern Island but have heard of recent use of Imiliq Island. Cape Wilson was identified to us after the 2010 survey by our survey guide. There may still be other unknown haulout sites.

If a haulout is disturbed shortly before the survey, a large number of animals can be dispersed and not counted. Bears reside on Manning Island where they seem to co-exist uneventfully most of the time but where they are also clearly watchful for an opportunity to catch a walrus. Seizing such an opportunity can clear a haulout. In 2010, the boat survey participants counted over 400 walrus at South Ooglit Island on 11 September before the aerial survey but they landed on the island causing animals to leave the haulout. Walrus were offshore during the

Table 2. Estimates of walrus abundance based on the 2010 and 2011 surveys. MCP_{HO} = minimum counted population of walrus hauled out; $MCP_{HO}/0.74$ = MCP_{HO} adjusted to account for walrus not hauled out at the time of the surveys using the weighted average from Table 1; and MCP_{HO}/% tags dry = MCP_{HO} adjusted to account for walrus not hauled out at the time of the surveys using the proportion of Foxe Basin satellite tags 'dry' at the time of the surveys; CV = Coefficient of Variation. See Results and Discussion sections for more details.

SURVEY			HAULOUT COUNTS	ADJUSTMENTS TO HAULOUT COUNTS		COMMENTS
Year	**Date**	**Haulouts surveyed**	**MCP_{HO}**	**$MCP_{HO}/0.74$ (CV)**	**MCP_{HO}/% tags dry (CV)**	
2010	29-30 August	Six haulouts	3,861	5,200 (0.022)		No active satellite tags.
	12-13 September	Two haulouts	2,409		6,480 (0.383)	Eight tags transmitting.
2011	12-13 September	Six haulouts	6,033	8,153 (0.021)		Eighteen tags transmitting; all but one near a disturbed haulout.
	19 September	Five haulouts	4,484		13,452[†] (0.43)	Twelve tags transmitting; all but one near South Ooglit Island.
		South Ooglit Island	3,368		9,262 (0.42)	Eleven tags transmitting near South Ooglit Island.
		Three other haulouts	1,117			The combined estimate for South Ooglit Island (adjusted using tag data) and three other haulouts (unadjusted) is 10,379 (CV = 0.42).

[†] If the data from all twelve tags are representative of walrus haulout behaviour in Foxe Basin then this population estimate would apply.

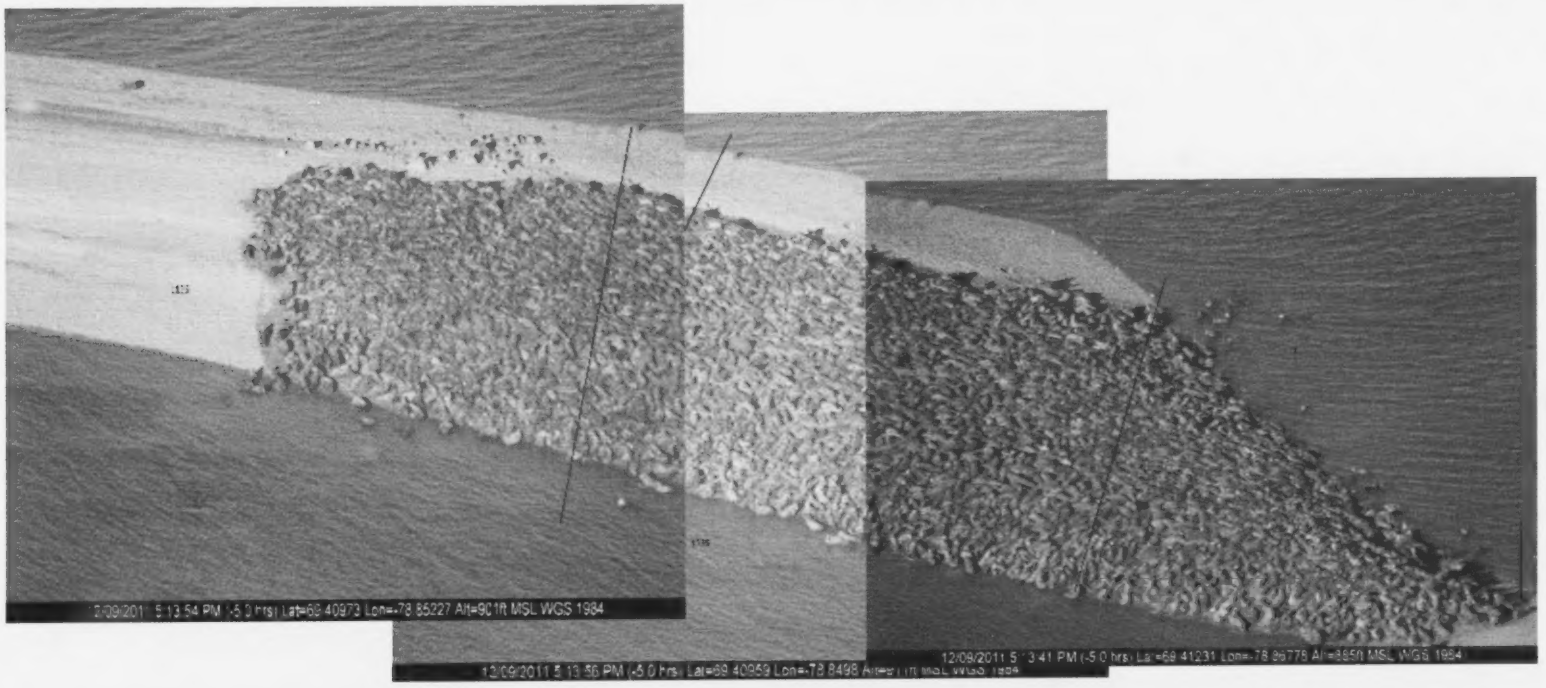

Figure 3. Example of oblique photographs used to count walrus on haulout sites, illustrating walrus densities. For data collection, each photo would be counted separately after demarcation lines were drawn.

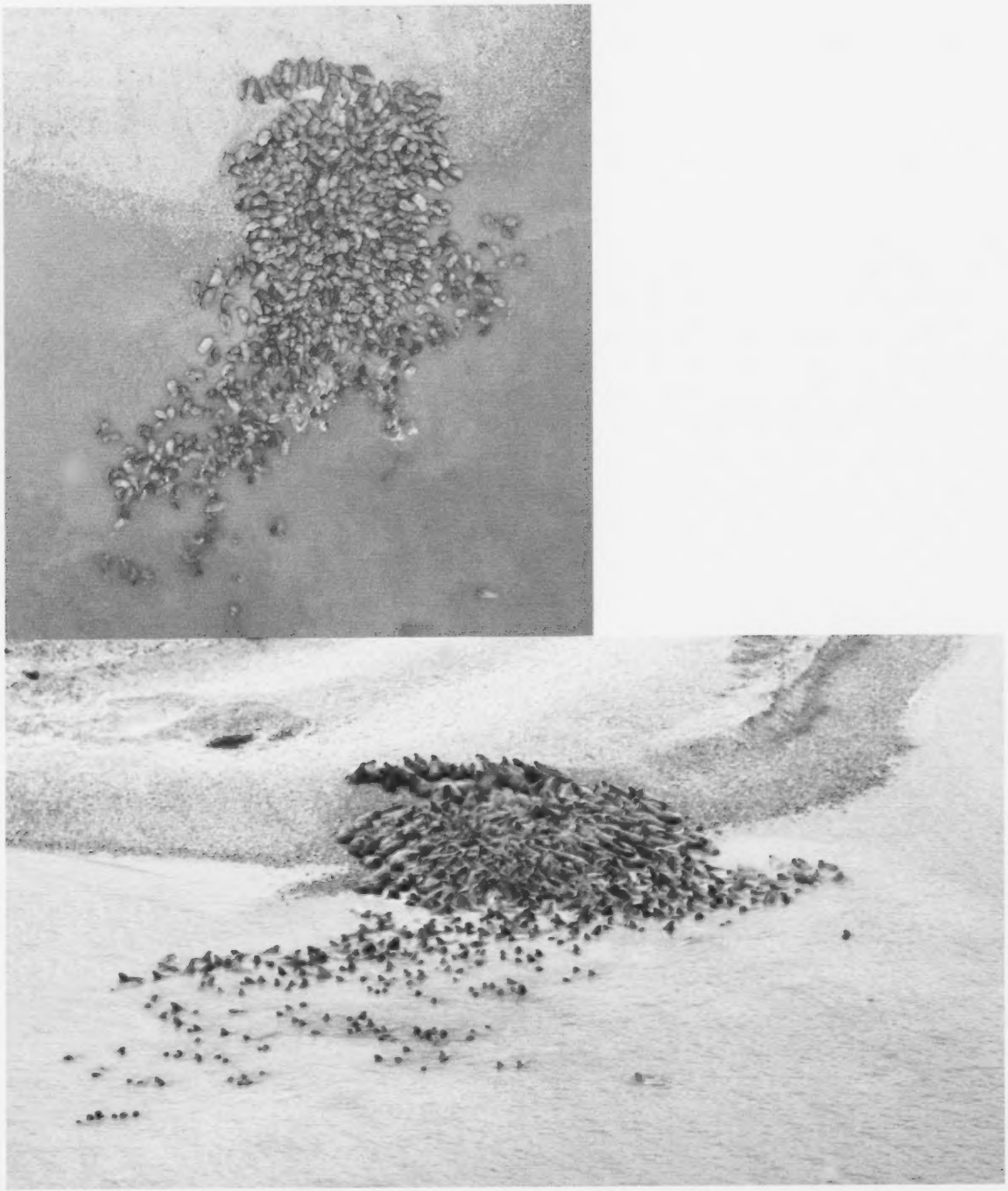

Figure 4. (upper) Vertical 3.7 cm resolution image and (lower) oblique image of the same haulout site photographed within two minutes of each other. The vertical image was captured using a Trimble AIC P65+ digital mapping camera with forward motion compensation at an altitude of 450 m and a speed of 210 kph. The oblique image was captured from a handheld DSLR camera at an altitude of 300 m, approximately 1,000 m offshore, at a speed of 210 kph.

aerial survey on 12-13 September where they could not be counted. The walrus may or may not have moved to Manning Island. Disturbance, incomplete coverage, and oblique photos all contribute to negatively-biased counts and estimates. If walrus in Foxe Basin move among haulouts more quickly than the time/distance criterion assumes, the final counts could be overestimates.

The use of the proportion of tags 'dry' during the hours of surveys is one way to adjust 'numbers hauled out' to obtain a total estimate. It requires that the tags be deployed well enough in advance of the survey that the tagged animals can resume normal behaviour, that the tagged animals are representative of age and sex classes in proportion to the population, and in general that the behaviour of the tagged walrus represents the behaviour of all the walrus in the area. In our particular case, the latter means that all walrus should be at a similar level of disturbance.

In 2010, the only walrus found at a suitable tagging site were at Manning Island after maximum counts were obtained. Tag data were applied to a later smaller count at which time preliminary analysis indicates some had visited two other haulouts approximately 80-90 km away.

In 2011, all walrus were tagged at South Ooglit Island over a few days and although one eventually travelled to another haulout approximately 170 km away, the rest remained within 50 km of where they had been tagged, in an area where there are no other haulout sites. Three of the four tags reporting 'dry' in the survey hour were tagged together within about 30 minutes on 2 September. These tag data may therefore reveal some synchrony of behavior within this small area which could affect the adjustment factor, but the data have yet to be analysed in that level of detail. The limited dispersion of tagged animals in Foxe Basin, however, does suggest the use of these tags to represent the whole of northern Foxe Basin is inappropriate. On the basis of this evaluation and the simple addition of another 1,117 counted but not adjusted, it appears there were 11,000+ walrus in northern Foxe Basin in September 2011. However, if these tags were representative, the count of 4,484 walrus hauled out on 19 September would be adjusted by 4/12 (0.33, CV = 0.43) and the population estimate would be 13,452 (CV = 0.43).

The final caveat about adjusting counts is that even with 10-20 tags functioning at the time the counts were made, the final estimate is sensitive to small changes in the number of tags reporting 'dry'. For example, adding one 'dry' tag to the 19 September 2011 data (5/11 instead of the observed 4/11, approximately a 20% difference) results in a 20% reduction of the estimated population size.

One final consideration is the state of flux that currently exists in the Arctic. Others have reported great variation in haulout occupancy both within and between years (Stewart *et al.* 2013a, c). 2010 was the first year in local memory that Foxe Basin was ice–free in September. 2011 was the second. In 2012 there was some ice and some walrus were seen on the ice, but neither local people nor DFO flight crews found substantial numbers of walrus. While this variability complicates the answer to "What is the real population size?" it also greatly affects the availability of walrus to hunters of Igloolik and Hall Beach.

CONCLUSION

In 2010, there were at least 3,900 walrus in the survey area in early September. There were likely 5,000+ based on an adjustment for the proportion at sea. There may have been about 6,500 if the behaviour of tagged animals was representative of all. In 2011, there were at least 6,000 walrus, conservatively adjusted to 8,100. The tags did not move to other haulouts and may not be representative of the whole area. On that assumption, there may have been 11,000 walrus present. Conversely, if the tag data were representative, there could have been almost

13,500 walrus present. There appears to be considerable variation in haulout use and numbers of walrus present within and between years.

ACKNOWLEDGEMENTS

We would like to acknowledge the communities of Hall Beach and Igloolik, the Hall Beach Hunters and Trappers Association and the Igloolik Hunters and Trappers Organization. Without their help and sharing of *Inuit qaujimaningit* this project would not have been possible. Support for this project was provided by the Polar Continental Shelf Project, the Nunavut Implementation Fund (DFO), Species at Risk Funding (DFO) and the Nunavut Wildlife Management Board. Kenn Borek Twin Otter and Universal Helicopter pilots provided flying services. Jack Orr, Zoya Martin, Brent Young, Levi Kaunak and David Angutirjuaq served as observers during the aerial surveys and we thank them for their assistance. We appreciate the care taken by N. Sader and J. Gierpy in counting walrus in photographs.

REFERENCES

Andersen, L.W., Born, E.W., Stewart, R.E.A., Dietz, R., Doidge, D.W., and Lanthier, C. 2013. A genetic comparison of West Greenland and Baffin Island (Canada) walruses: management implications. NAMMCO Sci. Publ. In press.

Buckland, S.T. and York, A.E. 2009. Abundance estimation. *In* Encyclopedia of marine mammals, second edition. Edited by W.F. Perrin, B. Würsig, and J.G.M. Thewissen. Academic Press, San Diego. 1,352 p.

DFO. 2002. Atlantic walrus. DFO Science stock status report E5-17, 18, 19, 20 (2002).

Dietz, R., Born, E.W., Stewart, R.E.A., Heide-Jørgensen, M.P., Stern, H., Rigét, F.F., Toudal, L., Lanthier, C., Villum Jensen, M., and Teilmann, J. 2013. Movements of walruses (*Odobenus rosmarus*) tracked with satellite transmitters between Central West Greenland and Southeast Baffin Island 2005-2008. NAMMCO Sci. Publ. In press.

Dixon, W. J. and Massey, F.J. 1969. Introduction to statistical analysis, third edition. McGraw-Hill, NY. 638 p.

Garlich-Miller, J.L. and Stewart, R.E.A. 1998. Growth and sexual dimorphism of Atlantic walrus (*Odobenus rosmarus rosmarus*) in Foxe Basin, Northwest Territories, Canada. Mar. Mamm. Sci. 14: 803–818.

Hills, S. 1992. The effect of spatial and temporal variability on population assessment of Pacific walruses. Thesis (Ph.D.) University of Maine, Orono, MA. 120 p.

Krebs, C.J. 1966. Demographic changes in fluctuating populations of *Microtus californicus*. Ecol. Monogr. 36: 239–273.

Lydersen, C., Aars, J., and Kovacs, K.M. 2008. Estimating the number of walruses in Svalbard from aerial surveys and behavioural data from satellite telemetry. Arctic 61: 119-128.

Olesiuk, P.F., Bigg, M.A., and Ellis, G.M. 1990. Recent trends in the abundance of harbour seals, *Phoca vitulina*, in British Columbia. Can. J. Fish. Aquat. Sci. 47: 992-1003.

Outridge, P.M. and Stewart, R.E.A. 1999. Stock discrimination of Atlantic walrus (*Odobenus rosmarus rosmarus*) in the eastern Canadian Arctic using lead isotope and element signatures in teeth. Can. J. Fish. Aquat. Sci. 56: 105–112.

Outridge, P.M., Davis, W.J., Stewart, R.E.A., and Born, E.W. 2003. Investigation of the stock structure of Atlantic walrus (*Odobenus rosmarus rosmarus*) in Canada and Greenland using dental Pb isotopes derived from local geochemical environments. Arctic 56: 82–90.

Shafer, A.B.A., Davis, C.S., Coltman, D.W., and Stewart, R.E.A. 2013. Microsatellite assessment of walrus (*Odobenus rosmarus rosmarus*) stocks in Canada. NAMMCO Sci. Publ. In press.

Stewart, R.E.A. 2008a. Can we calculate total allowable harvests for walrus using potential biological removal? DFO Can. Sci. Adv. Sec. Res Doc. 2008/025. iv + 13 p.

Stewart, R.E.A. 2008b. Redefining walrus stocks in Canada. Arctic 61: 292-308.

Stewart, R.E.A., Outridge, P.M., and Stern, R.A. 2003. Walrus life-history movements reconstructed from lead isotopes in annual layers of teeth. Mar. Mamm. Sci. 19: 806–818.

Stewart, R.E.A., Born, E.W., Dunn, J.B., Koski, W.R., and Ryan, A.K. 2013a.Use of multiple methods to estimate walrus (*Odobenus rosmarus rosmarus*) abundance in the Penny Strait-Lancaster Sound and West Jones Sound stocks, Canada. NAMMCO Sci. Publ. In press.

Stewart, R.E.A., Born, E.W., Dietz, R., Heide-Jørgensen, M.P., Rigét, F.F., Laidre, K., Villum Jensen, M., Knutsen, L.Ø., Fossette, S., and Dunn, J.B. 2013b. Abundance of Atlantic walrus in the Baffin Bay stock during summer. NAMMCO Sci. Publ. In press.

Stewart, R.E.A., Born, E.W., Dietz, R., and Ryan, A.K. 2013c. Estimates of minimum population size for walrus near southeast Baffin Island, Nunavut. NAMMCO Sci. Publ. In press.

Thompson, S.K. and Seber, G.A.F. 1994. Detectability in conventional adaptive sampling. Biometrics 50: 712-724.

Thompson, P.M., Tollit, D.J., Wood, D., Corpe, H.M., Hammond, P.S., and Mackay, A. 1997. Estimating harbour seal abundance and status in an estuarine habitat in north-east Scotland. J. Appl. Ecol. 34: 43-52.

Udevitz, M.S., Jay, C.V., Fischbach, A.S., and Garlich-Miller, J.L. 2009. Modeling haul-out behaviour of walruses in Bering Sea ice. Can. J. Zool. 87: 1111-1128.

Walker, R.S., Novara, A.J., and Perovic, P.G. 2008. Comparison of two methods for estimation of abundance of mountain vizcachas (*Lagidium viscacia*) based on direct counts. Mastazoologicia Neotropical. 15:1 35-140.

Zar, J.H. 1999. Biostatistical analysis, fourth edition. Prentice Hall, Upper Saddle River, NJ. 662 p.